

$eval((\lambda r . (\lambda g . g(3 - 1, g)))(\lambda m, h . \text{if } m > 1 \text{ then } (\lambda d.h(m - 1, h) (r := (*r) * m)) \text{ else halt } (*r))) (\text{ref } 3))$	$\xrightarrow{!^*}$
$eval(((\lambda r . ((\lambda g . (g, (3, 1) \curvearrowright -, g) \curvearrowright app), \lambda m, h . \%G) \curvearrowright app), 3 \curvearrowright \text{ref}) \curvearrowright app)$	$\xrightarrow{(1)}$
$result(k(((\lambda r . ((\lambda g . (g, (3, 1) \curvearrowright -, g) \curvearrowright app), \lambda m, h . \%G) \curvearrowright app), 3 \curvearrowright \text{ref}) \curvearrowright app) \text{ store}(\cdot) \text{ nextLoc}(0) \text{ env}(\cdot))$	$\xrightarrow{[K]}$
$result(k((\lambda r . ((\lambda g . (g, (3, 1) \curvearrowright -, g) \curvearrowright app), \lambda m, h . \%G) \curvearrowright app) \curvearrowright (3 \curvearrowright \text{ref}, \cdot) \curvearrowright app) \text{ store}(\cdot) \text{ nextLoc}(0) \text{ env}(\cdot))$	$\xrightarrow{(4)}$
$result(k(\text{closure}(r, ((\lambda g . (g, (3, 1) \curvearrowright -, g) \curvearrowright app), \lambda m, h . \%G) \curvearrowright app, \cdot) \curvearrowright (3 \curvearrowright \text{ref}, \cdot) \curvearrowright app) \text{ store}(\cdot) \text{ nextLoc}(0) \text{ env}(\cdot))$	$\xrightarrow{[K]}$
$result(k(3 \curvearrowright \text{ref} \curvearrowright (\cdot, \text{closure}(r, ((\lambda g . (g, (3, 1) \curvearrowright -, g) \curvearrowright app), \lambda m, h . \%G) \curvearrowright app, \cdot)) \curvearrowright app) \text{ store}(\cdot) \text{ nextLoc}(0) \text{ env}(\cdot))$	$\xrightarrow{(8), [K]}$
$result(k(\text{loc}(0) \curvearrowright (\cdot, \text{closure}(r, ((\lambda g . (g, (3, 1) \curvearrowright -, g) \curvearrowright app), \lambda m, h . \%G) \curvearrowright app, \cdot)) \curvearrowright app) \text{ store}((0, 3)) \text{ nextLoc}(1) \text{ env}(\cdot))$	$\xrightarrow{[K]}$
$result(k((\text{closure}(r, ((\lambda g . (g, (3, 1) \curvearrowright -, g) \curvearrowright app), \lambda m, h . \%G) \curvearrowright app, \cdot), \text{loc}(0)) \curvearrowright app) \text{ store}((0, 3) \cdot) \text{ nextLoc}(1) \text{ env}(\cdot))$	$\xrightarrow{(5), [K]}$
$result(k((\lambda g . (g, ((3, 1) \curvearrowright -, g) \curvearrowright app) \curvearrowright (\lambda m, h . \%G, \cdot) \curvearrowright app \curvearrowright (\cdot)) \text{ store}((0, 3)(1, \text{loc}(0))) \text{ nextLoc}(2) \text{ env}((r, 1)))$	$\xrightarrow{(4), [K]}$
$result(k((\text{closure}(g, (g, ((3, 1) \curvearrowright -, g) \curvearrowright app, (r, 1)), \%C1) \curvearrowright app \curvearrowright (\cdot)) \text{ store}((0, 3)(1, \text{loc}(0)) \cdot) \text{ nextLoc}(2) \text{ env}((r, 1)))$	$\xrightarrow{(5), [K]}$
$result(k(g \curvearrowright (((3, 1) \curvearrowright -, g, \cdot) \curvearrowright app \curvearrowright ((r, 1)) \curvearrowright (\cdot)) \text{ store}((0, 3)(1, \text{loc}(0))(2, \%C1)) \text{ nextLoc}(3) \text{ env}((g, 2)(r, 1)))$	$\xrightarrow{(3), [K]}$
$result(k((\%C1, 2, \%C1) \curvearrowright app \curvearrowright ((r, 1)) \curvearrowright (\cdot)) \text{ store}((0, 3)(1, \text{loc}(0))(2, \%C1) \cdot) \text{ nextLoc}(3) \text{ env}((g, 2)(r, 1)))$	$\xrightarrow{(5), [K]}$
$result(k(m \curvearrowright (1, \cdot) \curvearrowright \geq \%IF \curvearrowright ((g, 2)(r, 1)) \curvearrowright ((r, 1)) \curvearrowright (\cdot)) \%S1)$	$\xrightarrow{(3), [K]}$
$result(k(\text{bool}(\text{true}) \curvearrowright \%IF \curvearrowright \%e1) \%S1)$	$\xrightarrow{(6), [K]}$
$result(k((\lambda d.(h, ((m, 1) \curvearrowright -, h) \curvearrowright app) \curvearrowright ((r, ((r \curvearrowright *), m) \curvearrowright *) \curvearrowright \curvearrowright \cdot) \curvearrowright app \curvearrowright \%e1) \%S1)$	$\xrightarrow{(4, 3), [K]}$
$result(k(\text{loc}(0) \curvearrowright * \curvearrowright (m, \cdot) \curvearrowright * \curvearrowright (\cdot, \text{loc}(0)) \curvearrowright \curvearrowright \cdot, \%C2) \curvearrowright app \curvearrowright \%e1) \%S1)$	$\xrightarrow{(9), [K]}$
$result(k(m \curvearrowright (\cdot, 3) \curvearrowright * \curvearrowright (\cdot, \text{loc}(0)) \curvearrowright \curvearrowright \cdot, \%C2) \curvearrowright app \curvearrowright \%e1) \%S1)$	$\xrightarrow{(3), [K]}$
$result(k((\text{loc}(0), 6) \curvearrowright \curvearrowright \cdot, \%C2) \curvearrowright app \curvearrowright \%e1) \text{ store}((0, 3) \%s1) \text{ nextLoc}(5) \text{ env}((h, 4)(m, 3)(r, 1)))$	$\xrightarrow{(10), [K]}$
$result(k((\%C2, 6) \curvearrowright app \curvearrowright \%e1) \text{ store}((0, 6) \%s1 \cdot) \text{ nextLoc}(5) \text{ env}((h, 4)(m, 3)(r, 1)))$	$\xrightarrow{(5), [K]}$
$result(k(h \curvearrowright (((m, 1) \curvearrowright -, h, \cdot) \curvearrowright app \curvearrowright \%e2) \text{ store}((0, 6) \%s1 (5, 6)) \text{ nextLoc}(6) \text{ env}((d, 5)(h, 4)(m, 3)(r, 1)))$	$\xrightarrow{(3), [K]}$
$result(k((\%C1, 1, \%C1) \curvearrowright app \curvearrowright \%e2) \text{ store}((0, 6) \%s1 (5, 6) \cdot) \text{ nextLoc}(6) \text{ env}((d, 5)(h, 4)(m, 3)(r, 1)))$	$\xrightarrow{(5), [K]}$
$result(k(m \curvearrowright (1, \cdot) \curvearrowright \geq \%IF \curvearrowright \%e3) \%S2)$	$\xrightarrow{(3), [K]}$
$result(k(\text{bool}(\text{false}) \curvearrowright \%IF \curvearrowright \%e3) \%S2)$	$\xrightarrow{(7)}$
$result(k(r \curvearrowright * \curvearrowright \text{halt} \curvearrowright \%e3) \%S2)$	$\xrightarrow{(3)}$
$result(k(\text{loc}(0) \curvearrowright * \curvearrowright \text{halt} \curvearrowright \%e3) \%S2)$	$\xrightarrow{(9)}$
$result(k(6 \curvearrowright \text{halt} \curvearrowright \%e3) \%S2)$	$\xrightarrow{(11)}$
$result(k(6) \%S2)$	$\xrightarrow{(2)}$
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$\%IF$ stands for $if((\lambda d.(r, (r \curvearrowright *, m) \curvearrowright *) \curvearrowright \curvearrowright \cdot)((h, (m, 1) \curvearrowright -, h) \curvearrowright app), r \curvearrowright * \curvearrowright \text{halt})$
 $\%G$ stands for $(m, 1) \curvearrowright > \curvearrowright \%IF$
 $\%C1$ stands for $\text{closure}(m, h, \%G, (r, 1))$
 $\%S1$ stands for $\text{store}((0, 3) \%s1) \text{ nextLoc}(5) \text{ env}((h, 4)(m, 3)(r, 1))$
 $\%e1$ stands for $((g, 2)(r, 1)) \curvearrowright ((r, 1)) \curvearrowright (\cdot)$
 $\%C2$ stands for $\text{closure}(d, (h, ((m, 1) \curvearrowright -, h) \curvearrowright app, (h, 4)(m, 3)(r, 1))$
 $\%s1$ stands for $(1, \text{loc}(0))(2, \%C1)(3, 2)(4, \%C1)$
 $\%e2$ stands for $((h, 4)(m, 3)(r, 1)) \curvearrowright \%e1$
 $\%e3$ stands for $((d, 5)(h, 4)(m, 3)(r, 1)) \curvearrowright \%e2$
 $\%S2$ stands for $\text{store}((0, 6) \%s1 (5, 6)(6, 1)(7, \%C1)) \text{ nextLoc}(8) \text{ env}((h, 7)(m, 6)(r, 1))$

Figure 2: Sample run of the factorial program in the executable semantics of λ_K in K .